Discovering the First Galaxy Group with IXO

Thomas Reiprich

Heinz Andernach, Helen Eckmiller, Holger Israel, Vera Jaritz, Brenda Miranda Ocejo, Yu-Ying Zhang

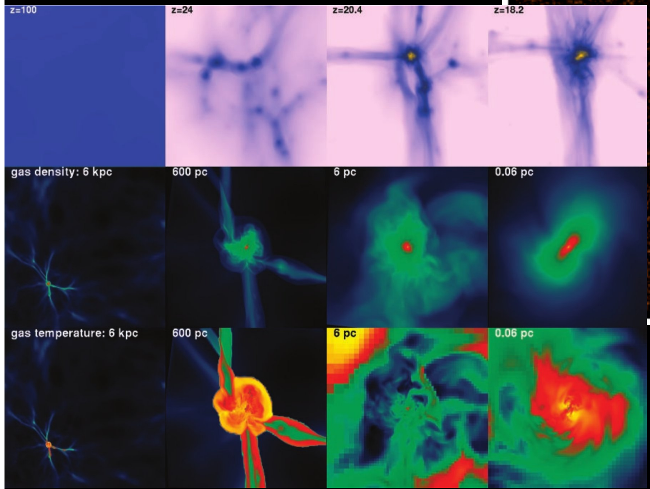
+ (associated) Kaustuv Basu, Thomas Erben, Florian Pacaud, Jennifer Piel, Daniela Wuttke

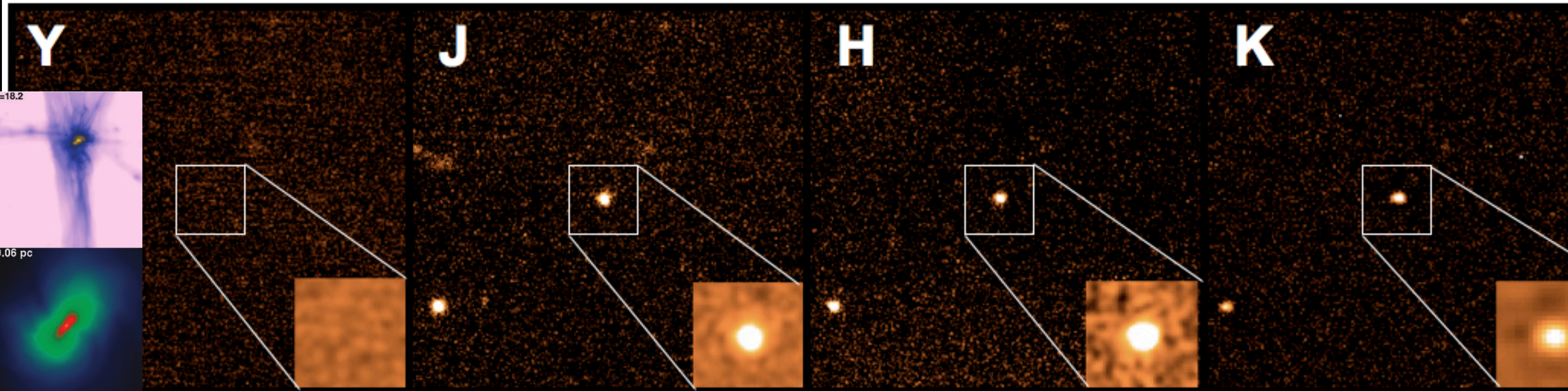
+ (former) Aleksi Halkola, Daniel Hudson, Richard Hanson, Rupal Mittal

Emmy Noether Research Group
Argelander Institute for Astronomy
Bonn University
http://www.dark-energy.net

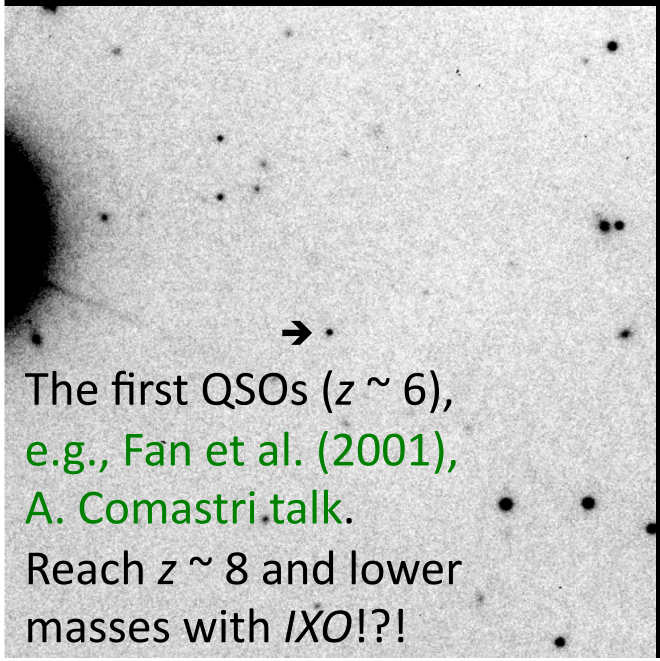
Quest for the First Objects

The first star, e.g., Abel et al. (2002).

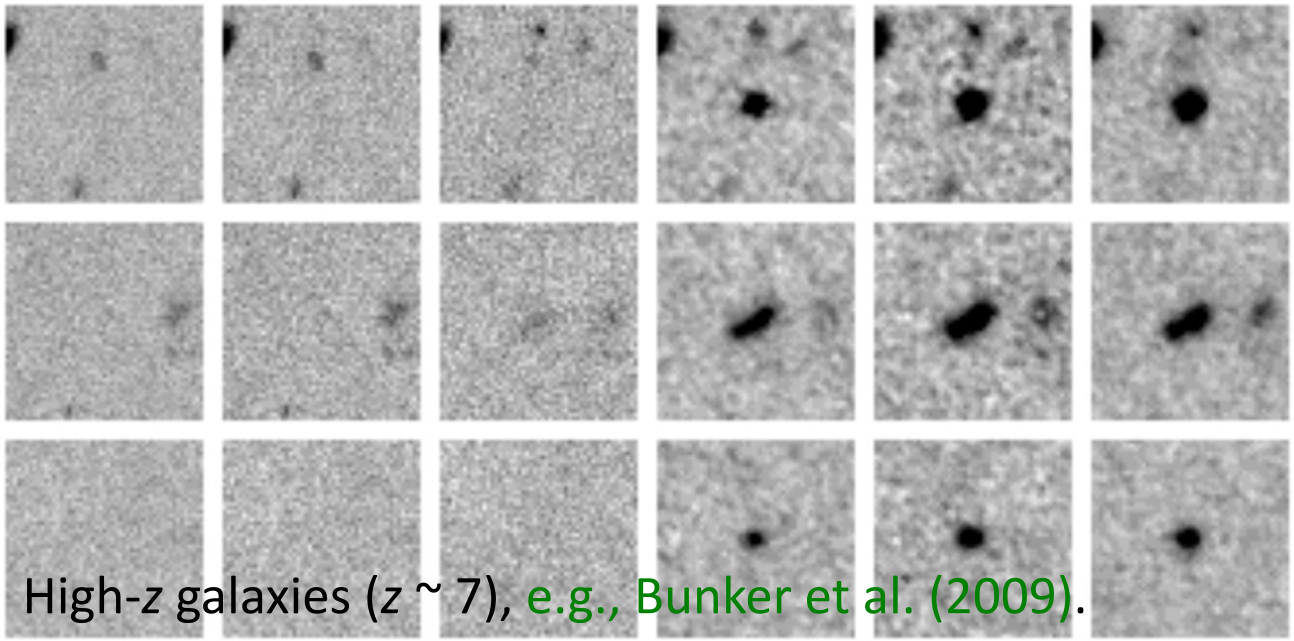




High-z GRBs (z ~ 8), e.g., Tanvir et al. (2009), Salvaterra et al. (2009).



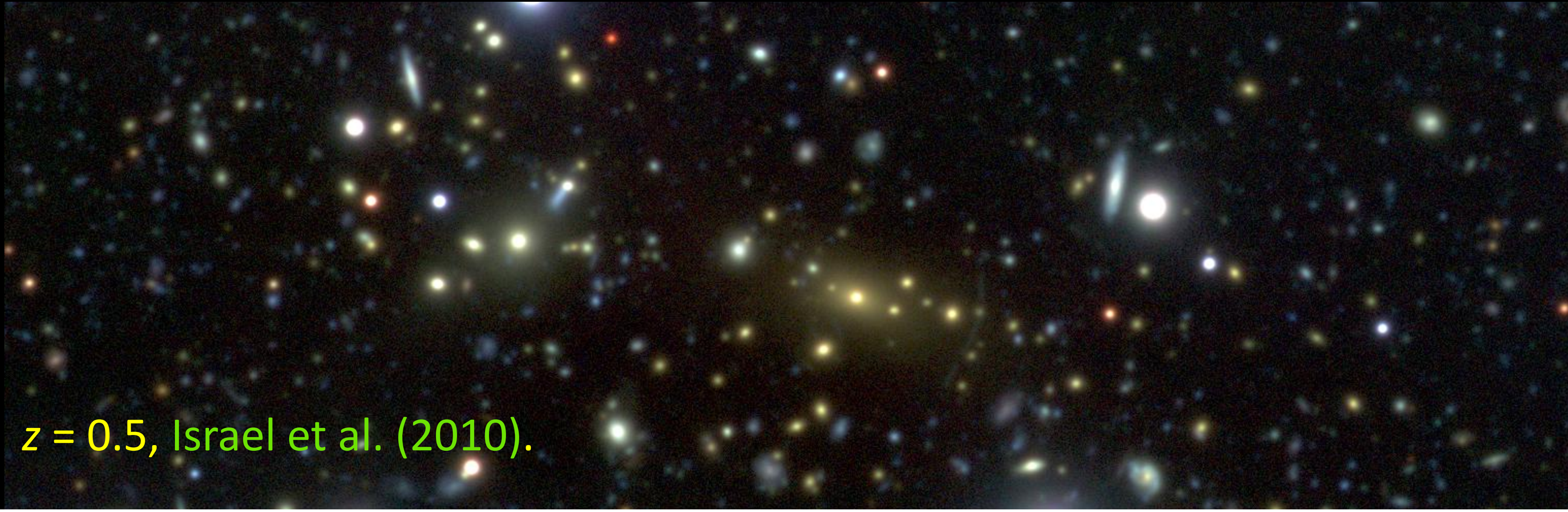
The first QSOs (z ~ 6), e.g., Fan et al. (2001), A. Comastri talk.
Reach z ~ 8 and lower masses with *IXO*!?!



High-z galaxies (z ~ 7), e.g., Bunker et al. (2009).

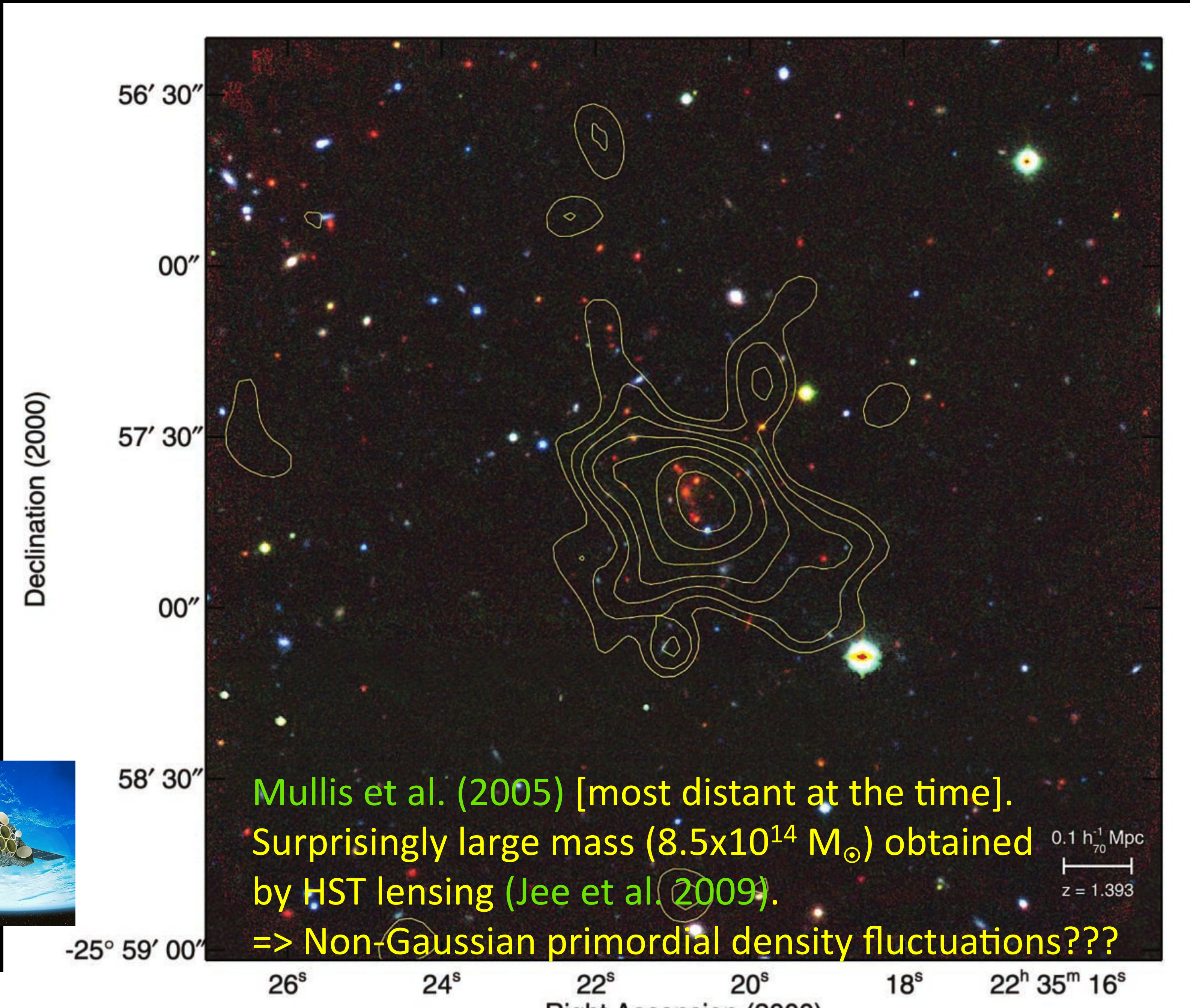
What About the First *BIG* Objects?

- *eROSITA* will find ALL *massive* galaxy clusters in the Universe, including the first one.
- May *IXO* detect the first galaxy group; i.e., the first object significantly bigger than a galaxy emitting X-rays due to gravitational collapse?



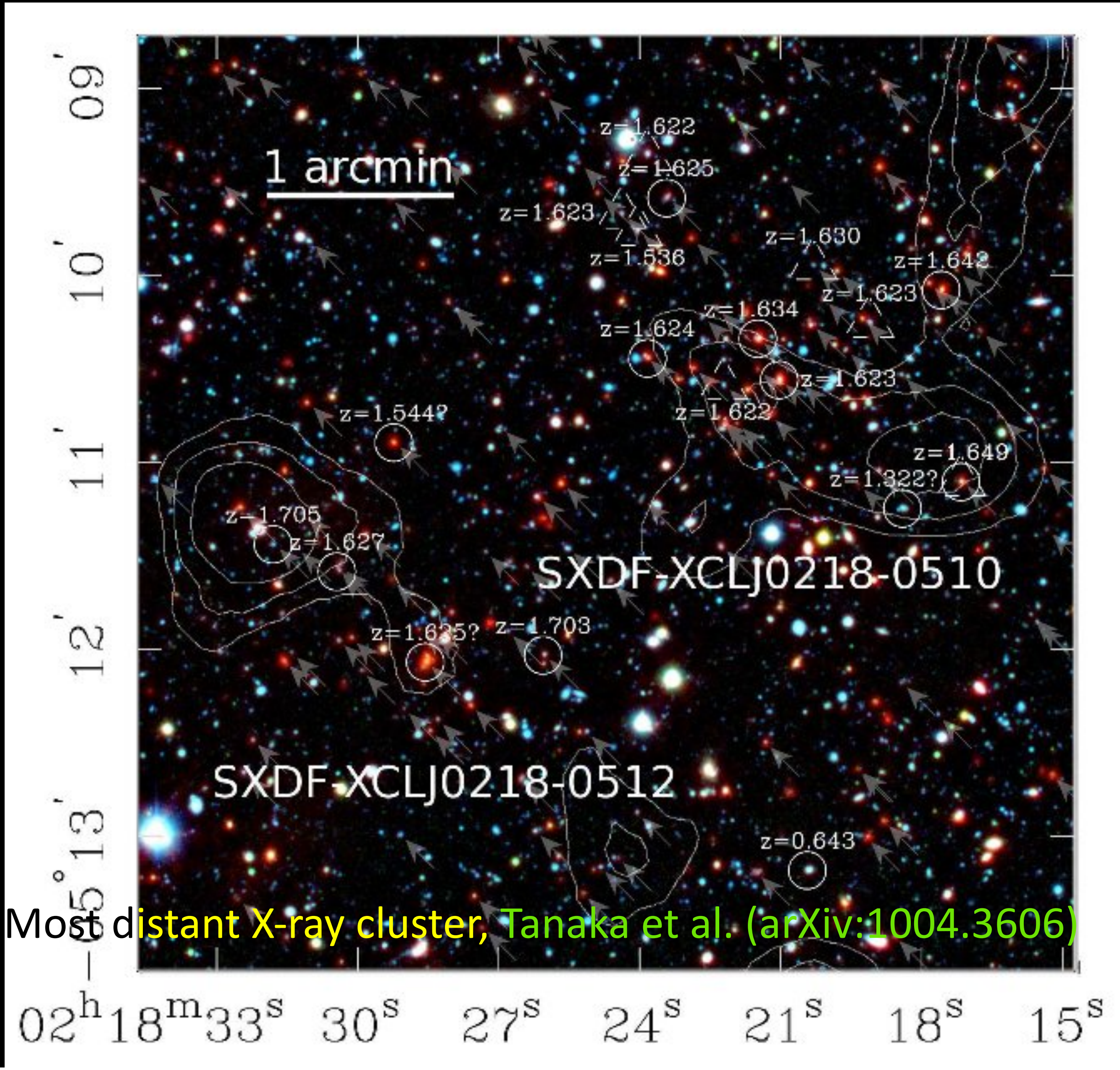
z = 0.5, Israel et al. (2010).

X-Ray Selected, Massive Cluster at z = 1.4



Mullis et al. (2005) [most distant at the time].
Surprisingly large mass ($8.5 \times 10^{14}\ M_{\odot}$) obtained by HST lensing (Jee et al. 2009).
=> Non-Gaussian primordial density fluctuations???

X-Ray Cluster at z = 1.6

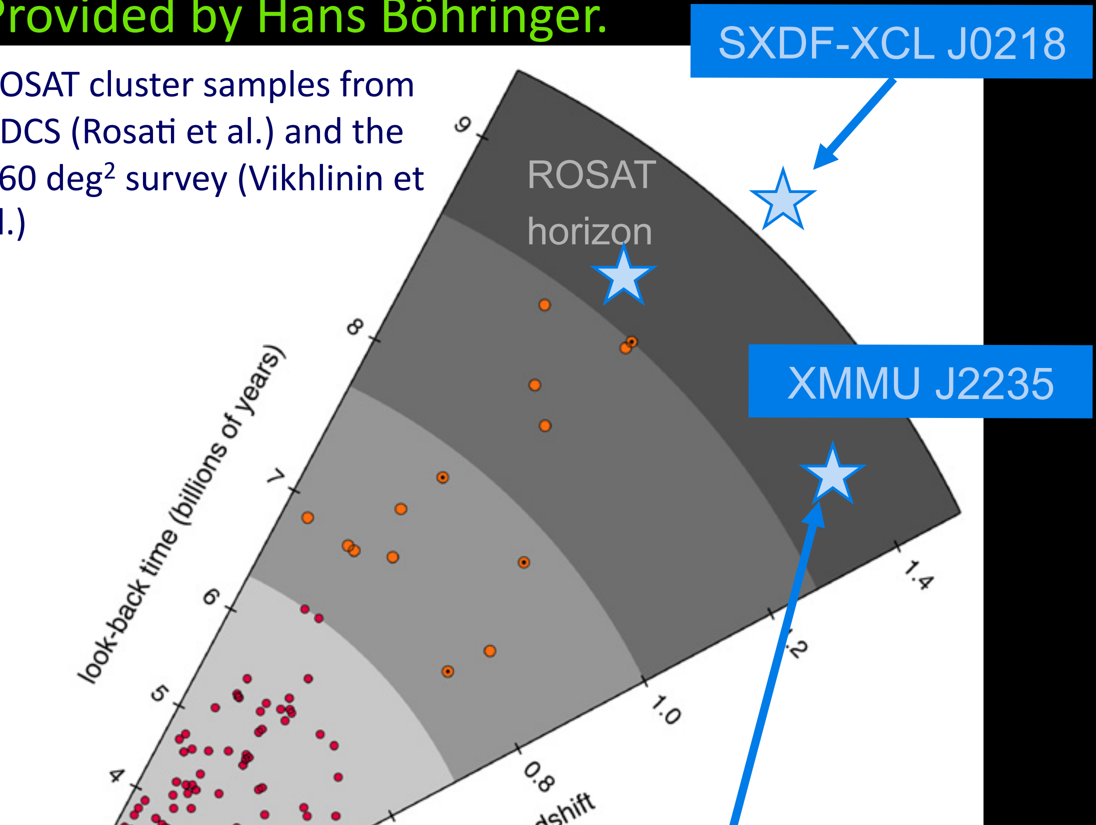


Most distant X-ray cluster, Tanaka et al. (arXiv:1004.3606)

IXO-GR J0633

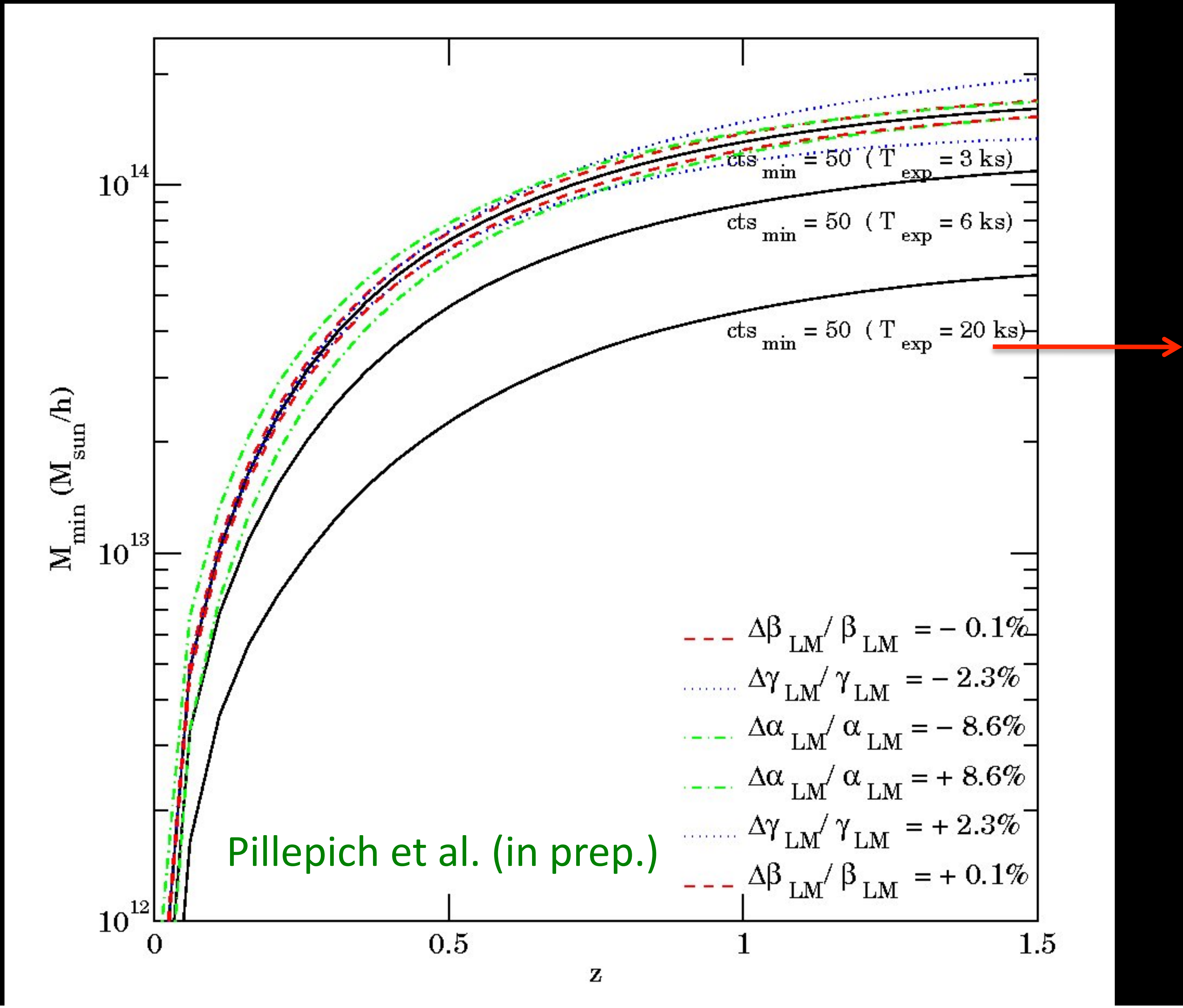
Provided by Hans Böhringer.

ROSAT cluster samples from RDCS (Rosati et al.) and the 160 deg^2 survey (Vikhlinin et al.)

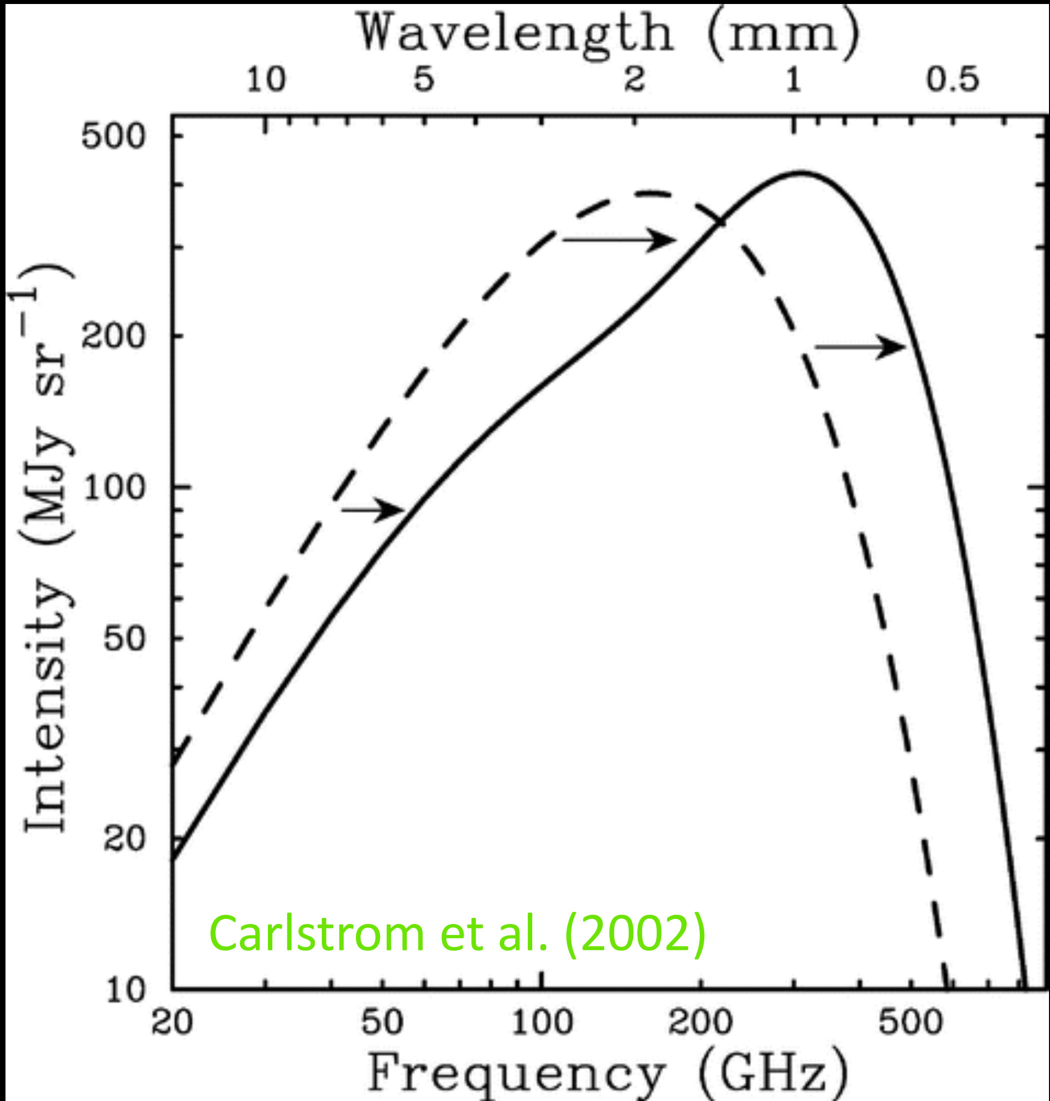


eROSITA Mass Limit

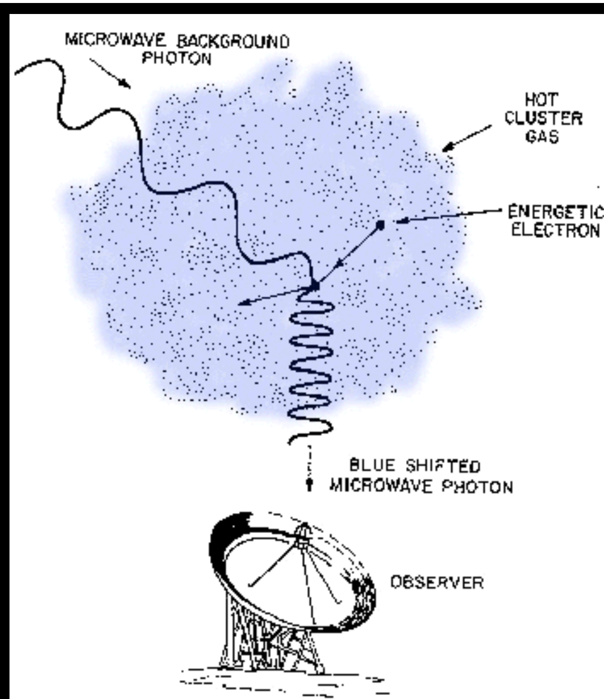
eROSITA will find ALL *massive* clusters in the Universe, but no *high-z* groups.



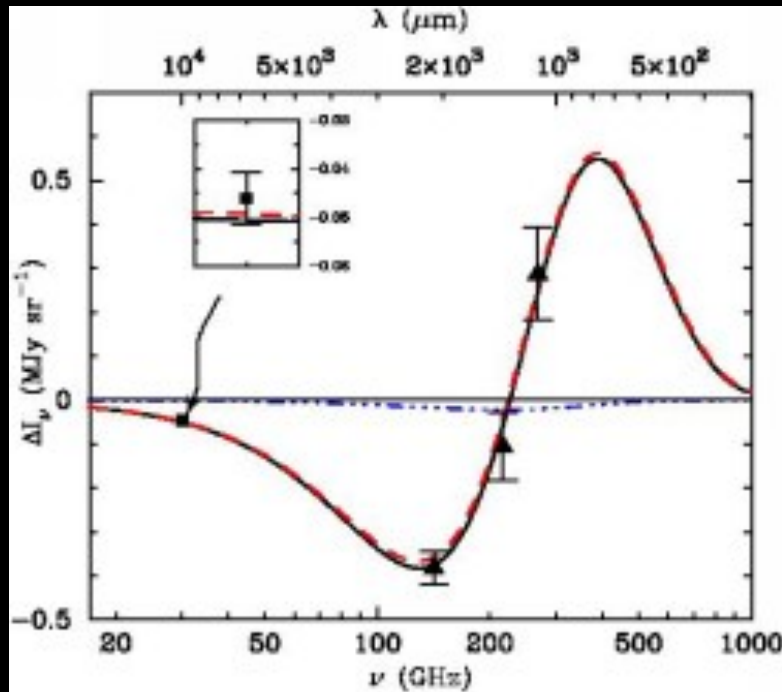
Sunyaev-Zeldovich Effect



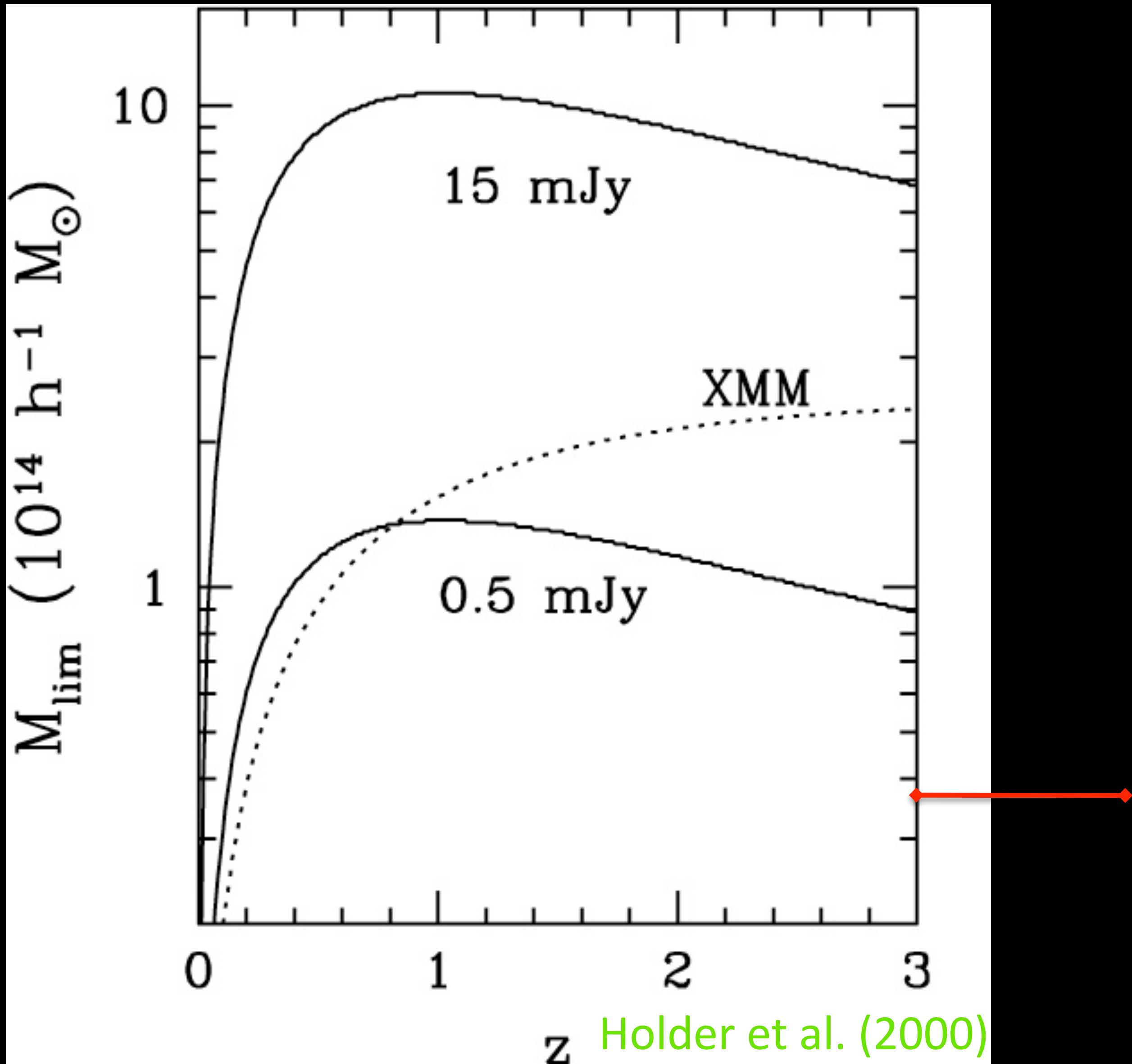
Carlstrom et al. (2002)



http://www.astro.uchicago.edu/sza/primer.html

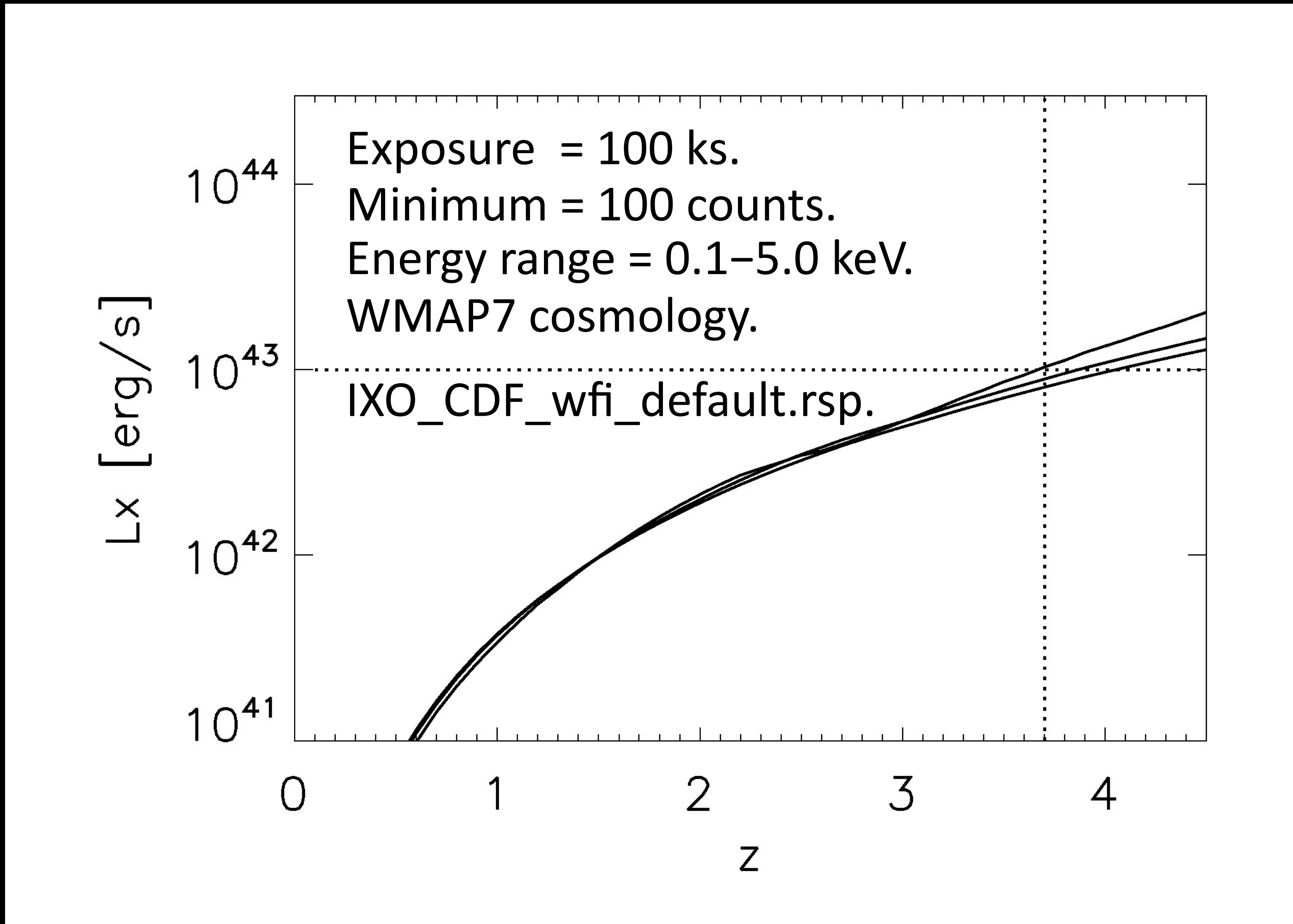


Limiting Mass for SZ Surveys



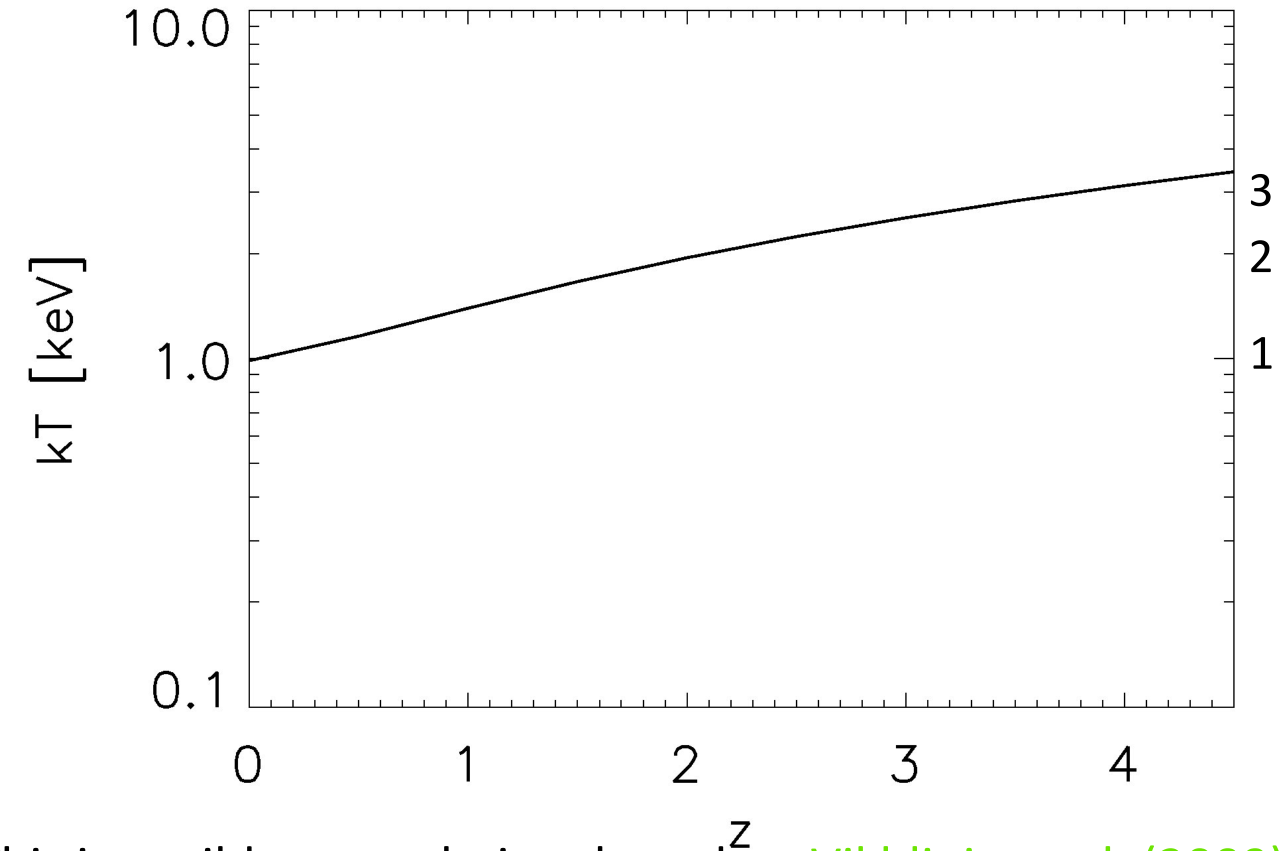
Holder et al. (2000)

IXO L_X Limit



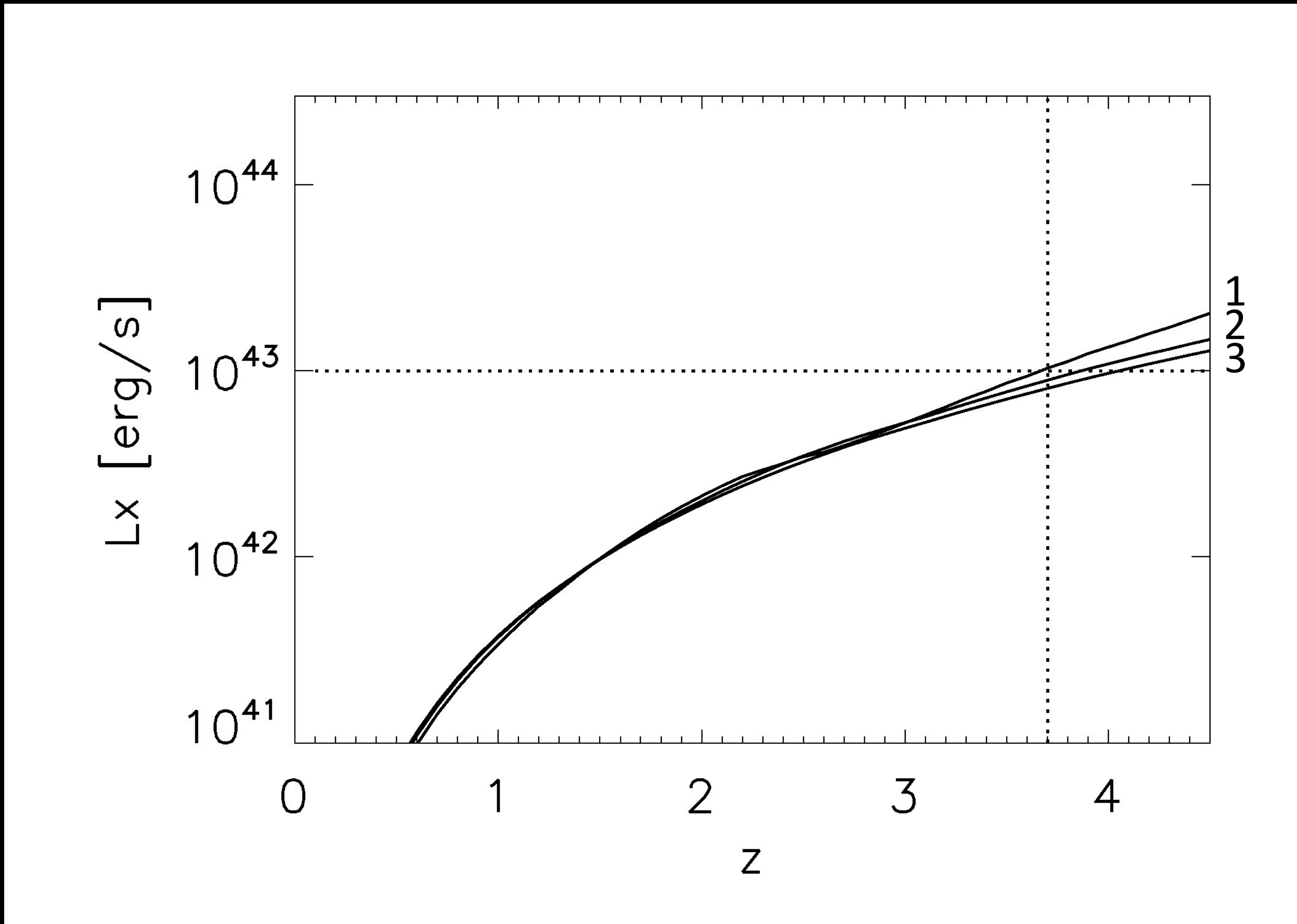
Exposure = 100 ks.
Minimum = 100 counts.
Energy range = 0.1−5.0 keV.
WMAP7 cosmology.
IXO_CDF_wfi_default.rsp.
10^{44}
10^{43}
10^{42}
10^{41}
Lx [erg/s]
0
1
2
3
4
z

$T_X(z)$ for M_{200} = 5x10^{13} M$_\odot$

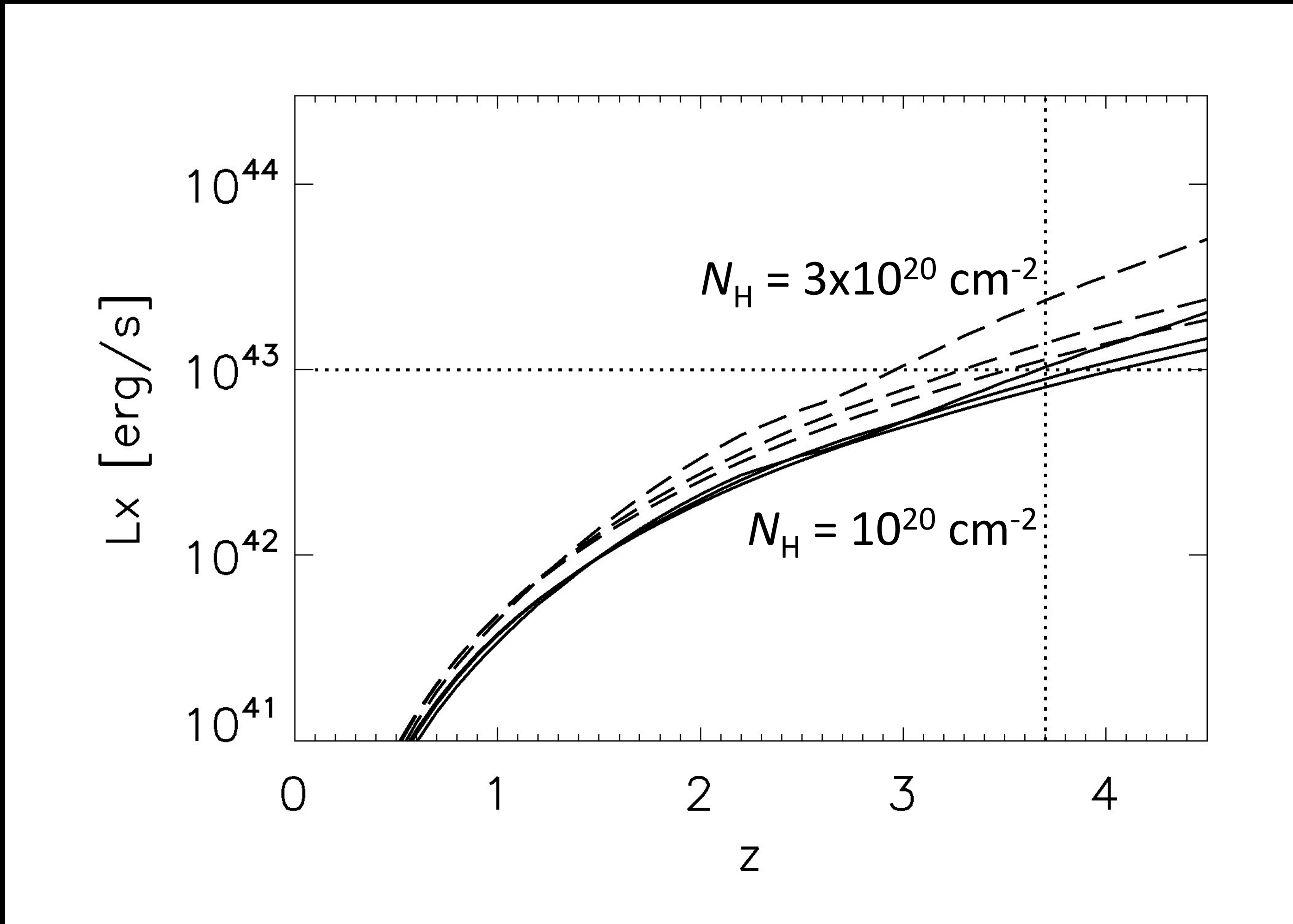


[This is a wild extrapolation, based on Vikhlinin et al. (2009).]

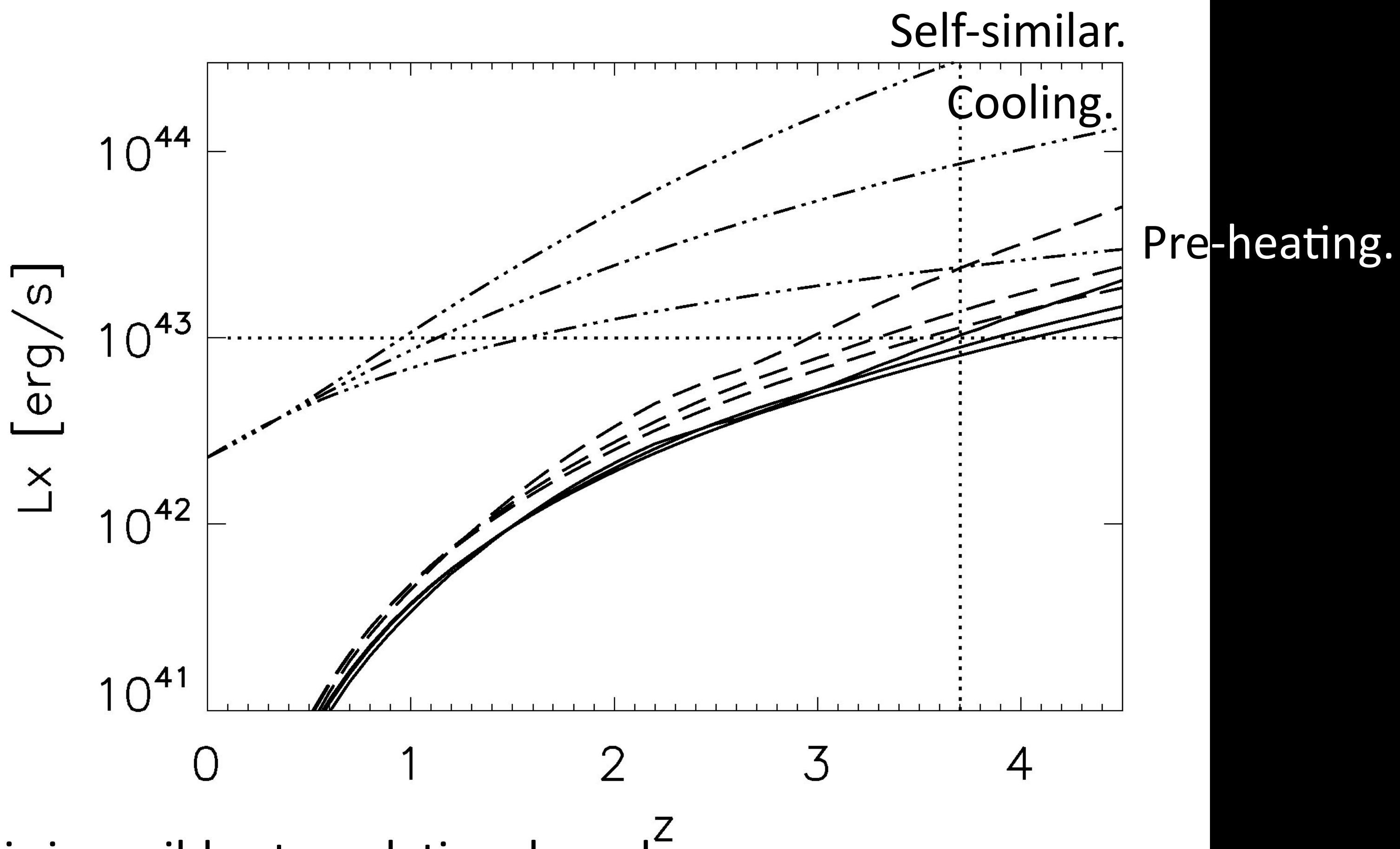
IXO L_X Limit



IXO L_X Limit

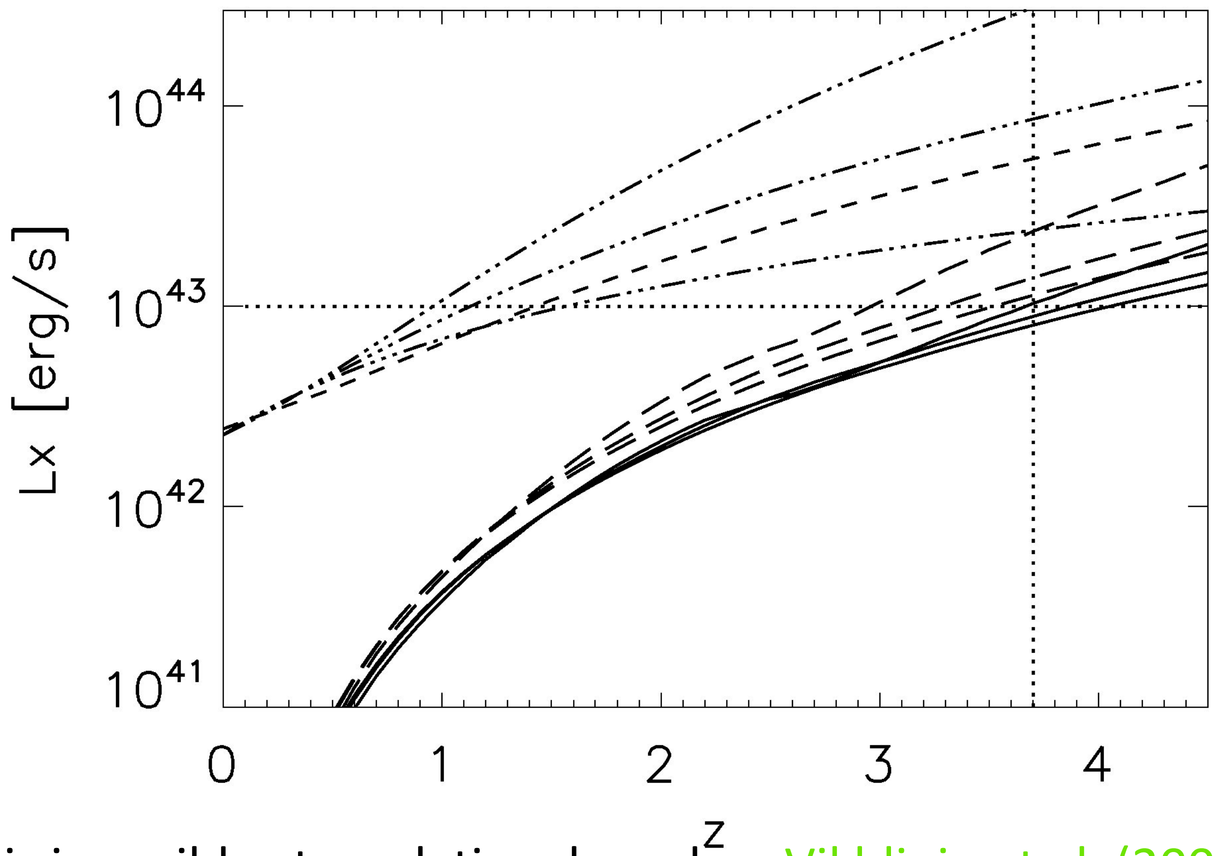


$L_X(z)$ for $M_{200} = 5\text{x}10^{13}\ M_\odot$



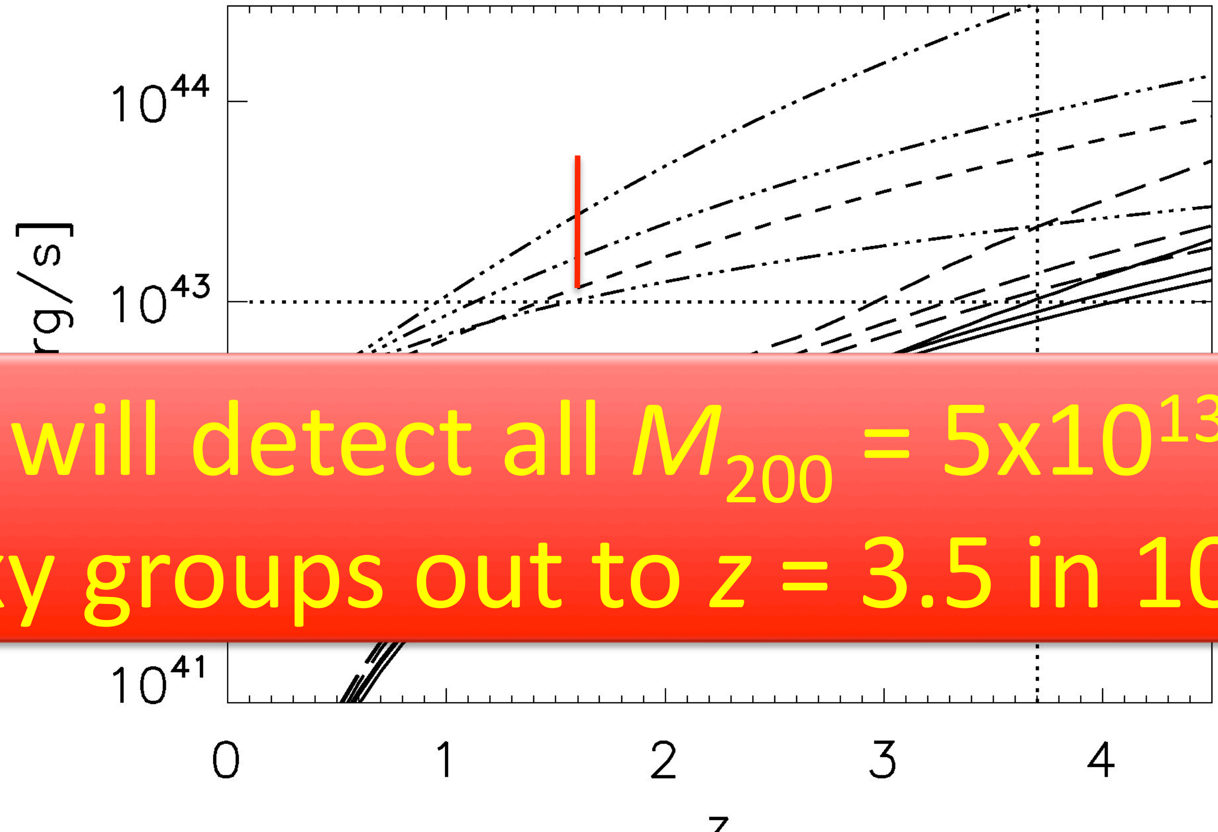
[This is a wild extrapolation, based on
Arnaud & Evrard (1999) + Arnaud, Pointecouteau, Pratt (2005)
+ Voit (2005); provided by Florian Pacaud.]

$L_X(z)$ for $M_{200} = 5\text{x}10^{13}\,M_\odot$



[This is a wild extrapolation, based on Vikhlinin et al. (2009).]

$L_X(z)$ for $M_{200} = 5 \times 10^{13}\ M_{\odot}$



IXO will detect all $M_{200} = 5 \times 10^{13}\ M_{\odot}$ galaxy groups out to $z = 3.5$ in 100 ks.

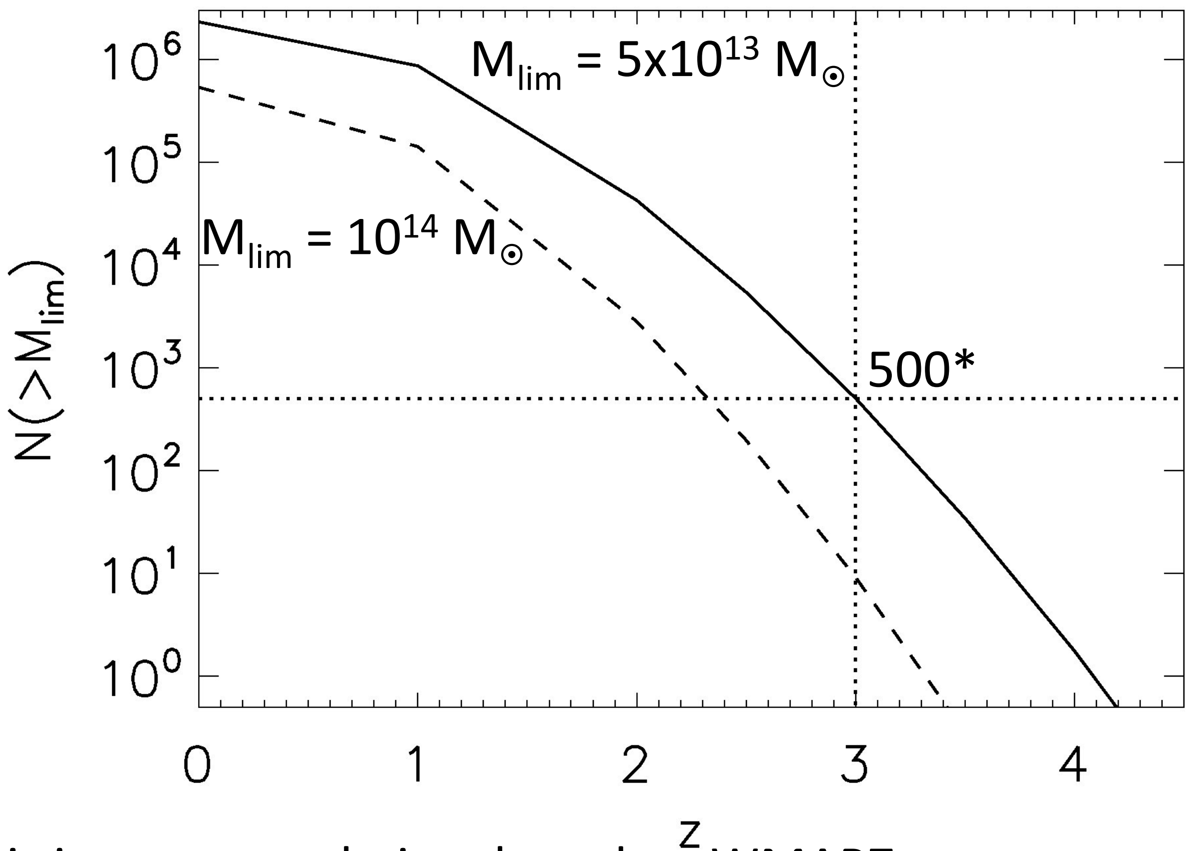
[This is a wild extrapolation, based on Vikhlinin et al. (2009).]

How many $M_{200} \geq 5\text{x}10^{13}\ \mathrm{M}_{\odot}$ galaxy groups exist in the Universe at $z > 3$?

500!*

[*This is an extrapolation, based on WMAP7 + Tinker et al. (2008); provided by Florian Pacaud.]

500 Groups



[*This is an extrapolation, based on WMAP7 + Tinker et al. (2008); provided by Florian Pacaud.]

How many $M_{200} \geq 5\text{x}10^{13}\ M_{\odot}$ galaxy groups exist in the Universe at $z > 3$?

500!*

Almost all of them emerge at $z < 3.5$.

The range $3.0 < z < 3.5$ is where the first galaxy groups form* and *IXO* can, in principle, discover them.

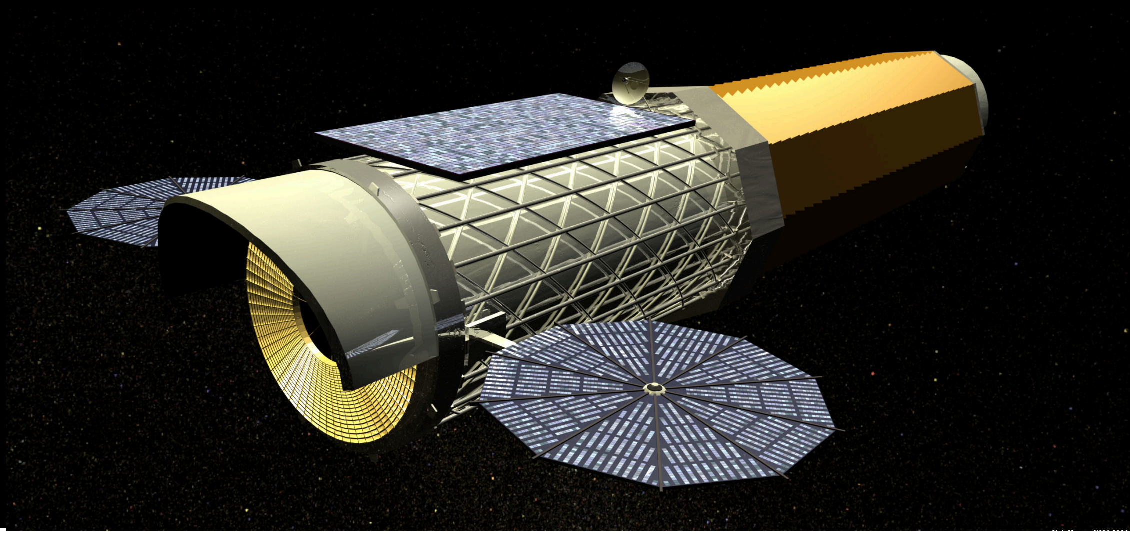
[*This is an extrapolation, based on WMAP7 + Tinker et al. (2008); provided by Florian Pacaud.]

Will *IXO* Detect any of the 500 Groups?

- To detect ≥ 1 group, need to cover
  ≥ 42,000 deg^2 / 500 = $\boxed{84\ \text{deg}^2.}$
- What sky area will *IXO* survey serendipitously per year?
  - *IXO* WFI field-of-view ≈
    18^2 arcmin^2 = 324 arcmin^2 = 0.09 deg^2 (or larger?).
  - 1 yr = 31,536 ks. 80% efficiency => 25,229 ks.
  - 50% of all observations suitable => 12,614 ks.
  - 126 pointings with 100 ks
    => 126*0.09 deg^2 = 11.34 deg^2 per year.
  - 84 deg^2 / 11.34 deg^2/yr = $\boxed{7.4\ \text{yr.}}$

Within ~10 years of normal operation *IXO* will discover one of the first galaxy groups in the Universe.

This is the ultimate structure formation test.
Should it detect >> 1, then something wrong, e.g., non-Gaussian primordial density perturbations or ???



Possible Pitfalls

- Smaller fraction of useful observations?
- More than 100 counts required for detection?
- PSF/AGN contamination?
- Strongly non-standard $L_X(z)$—M relation?
- Follow-up/ID will be challenging (→ ELT, …).
- Cosmology ≠ WMAP7?
- PSF/AGN contamination?
- Metallicity << 0.3?
- ….